Ship Suitability Testing – Preparing for the Future

Mr. Ronald J. Harney
Senior T&E Engineer for Ship Suitability
Naval Air Warfare Center, Aircraft Division
21950 Nickles Rd, Bldg 2649, Rm 207C
Patuxent River, MD, 20670
USA

ronald.harney@navy.mil

ABSTRACT

In support of the United States Navy Sea Power 21 initiative, ship suitability test and evaluation personnel are preparing to support a large number of test and evaluation programs. The pillars of Sea Power 21, which include Sea Basing, Sea Shield, and Sea Strike call for a diverse set of new and modified aircraft and air capable ships. Ship compatibility testing may be required on aircraft ranging from the two variants of the Joint Strike Fighter to the Firescout unmanned helicopter; and from C-130 cargo aircraft to small unmanned seaplanes. Additionally, aircraft compatibility testing will be required on ships ranging from the Littoral Combat Ship to the DDX destroyer, and from a new amphibious assault ship to the latest in nuclear carrier technology, CVN-21, which will incorporate all new electric catapult and arresting gear equipment. The precision approach landing systems group is already testing enabling technologies for a new GPS-based Joint Precision Approach and Landing System, which will significantly change the air traffic control environment, enable all aircraft to have precision approach capability, and provide the means to operate fighter-sized Unmanned Combat Air Vehicles on aircraft carriers. These aircraft/ship test and evaluation programs will require the development of new methodology. They will also require the testers to research and modify test techniques that have not been used for decades. We are also challenged to seek methods to minimize testing requirements and manpower while still giving the Fleet operator the maximum possible safe operating envelope. From rotary wing to tilt rotor to fixed wing aircraft and from hydroplanes to catamarans to the super carriers, the ship suitability test and evaluation group will be responsible for testing aircraft/ship compatibility in a highly dynamic and challenging environment. This presentation will provide a brief overview of the upcoming programs and discuss the test and evaluation challenges.

Harney, R.J. (2005) Ship Suitability Testing – Preparing for the Future . In *Flight Test – Sharing Knowledge and Experience* (pp. 7-1 – 7-14). Meeting Proceedings RTO-MP-SCI-162, Paper 7. Neuilly-sur-Seine, France: RTO. Available from: http://www.rto.nato.int/abstracts.asp.

1.0 INTRODUCTION

The United States Navy's Sea Power 21 initiative defines the requirements for all Navy forces from submarines to space. This initiative is broken down into three specific areas:

- Sea Basing
  - Project forces worldwide with capability to fight and win
  - Operate immediately from an expanded and secure maneuver area
  - Minimize vulnerabilities tied to overseas land support
- Sea Shield
  - Assure access throughout the battlespace for the Joint Force
  - Project defense around friends, allies, and coalition and Joint Forces
  - Provide a sea-based layer of homeland defense
- Sea Strike
  - Project decisive and persistent offensive power anywhere in the world
  - Launch immediate, agile and sustainable operations from the sea

In support of Sea Power 21 we are constantly upgrading current hardware while at the same time developing new hardware. While Ship Suitability Test and Evaluation (T&E) has a long history of ensuring air platforms and ship platforms are compatible, the Naval Air Systems Command (NAVAIR) has recognized that Fleet operators would benefit from increased up front communication between NAVAIR, responsible for the aviation interfaces, and the Naval Sea Systems Command (NAVSEA), responsible for the ship platform. To this end, a new Aviation/Ship Integration (A/SI) Program Management Team was formed backed by a new systems engineering arm to ensure the interface between air and sea platforms is addressed early in the design phase. This team leverages the engineering and technical expertise from NAVAIR to address all aspects of aviation/ship integration to include logistics, manpower, interoperability, Network Centric Warfare, and T&E. While Ship Suitability T&E has always been involved in the design stages of air platforms, the formation of the A/SI team has enabled the T&E community to be more effective by creating avenues for early involvement in development of ship aviation facilities and the definition of certification criteria. The timeliness of this effort is crucial as there are many new aviation platforms and aviation capable ships slated for test in the next five years. Ship Suitability T&E must be ready to test everything from new aircraft ranging from small UAV's to the two variants of the Joint Strike Fighter (JSF) and from ships ranging from the new DDX destroyer to the CVN 21 aircraft carrier. In order to conduct these test programs in today's lean environment, T&E methods must be re-evaluated to ensure test programs are as small as possible while recognizing the inherent risk of operating in the shipboard environment. This also includes ensuring a highly integrated developmental and operational test effort.

2.0 SHIP SUITABILITY T&E

2.1 Fixed-Wing Testing

The Fixed-Wing Ship Suitability T&E Branch performs all flying qualities, performance, and structural tests associated with Navy manned and unmanned fixed wing platforms. The bulk of the testing involves catapult and arrested landing structural demonstrations of new and modified aircraft. Structural demonstrations as well as steam ingestion catapult tests are conducted at shore based catapult and arrested landing facilities located at the Naval Air Warfare Center, Patuxent River, MD. This group also supports launch and recovery hardware developmental testing at the Naval Air Warfare Center, Lakehurst, New Jersey. Flying qualities and performance (FQ&P) testing is first conducted shore based, then evaluated at the ship. The shore-based tests are used to define the minimum acceptable approach airspeed and give the testers an initial look at airplane flying qualities in the more benign shore based environment. Once we are satisfied with the shore-based results from a structural suitability and a FQ&P standpoint, we then take the airplane to the ship. Some of the most exciting shipboard tests are the minimum catapult end airspeed tests where we determine the slowest safe speed for catapult flyaway. Other shipboard launch tests include establishing crosswind limits, evaluating launches off waist catapults, evaluating the affects of low energy launches (low gross weights, high winds) on flyaway, and determining aircraft trim requirements for symmetric and asymmetric store configurations. Recovery testing includes establishing crosswind limits, evaluating bolter and waveoff performance, and evaluating handling qualities at high wind-over-deck conditions. Additional testing includes evaluating compatibility with shipboard facilities and support equipment. Examples include conducting heavy weather tie down, canopy opening under high wind conditions, dynamic tipback following an arrestment, and hangar bay towing and spotting.

2.1 Rotary-Wing Testing

The Rotary-Wing Ship Suitability T&E Branch conducts the performance and compatibility tests of military and civilian manned and unmanned rotorcraft and rotorcraft systems in the shipboard operating environment for all classes of ships. The branch defines the structural and functional integrity of the aircraft and aircraft systems and aircraft handling and performance characteristics during takeoff, approach, and recovery operations, also referred to as Dynamic Interface (DI) testing. Similar to fixed-wing testing, structural suitability and initial FQ&P tests are conducted shore based. Shipboard tests are then conducted to define the operational wind-over-deck limits under normal and emergency conditions, evaluate deck lighting and marking under day and night conditions (aided and un-aided), and determine compatibility with visual landing aids and mechanical aids such as the Recovery Assist, Securing, and Traversing (RAST) system. The branch also evaluates the aircraft deck handling, servicing, storage, and support operations; and provides the Fleet with operating envelopes, limits, and interoperability recommendations. Since helicopters fly aboard or interface with just about all the ships in the Navy, the rotary wing testers are at sea evaluating new or modified ship configurations much more often than their fixed wing counterparts. This branch also conducts DI testing with Coast Guard ships and aircraft, and with Army and Air Force aircraft.

2.2 Air Traffic Control and Landing Systems Testing

The Air Traffic Control and Landing Systems (ATC&LS) Branch performs T&E on all airborne, shipboard, and shore based electronic, electro-optical, satellite, and visual ATC&LS. The primary Precision Approach Landing Systems (PALS) on a CV/CVN (Figure 1) are the AN/SPN-46 Automatic Carrier Landings System (ACLS) and the AN/SPN-41 Instrument Carrier Landing System (ICLS).

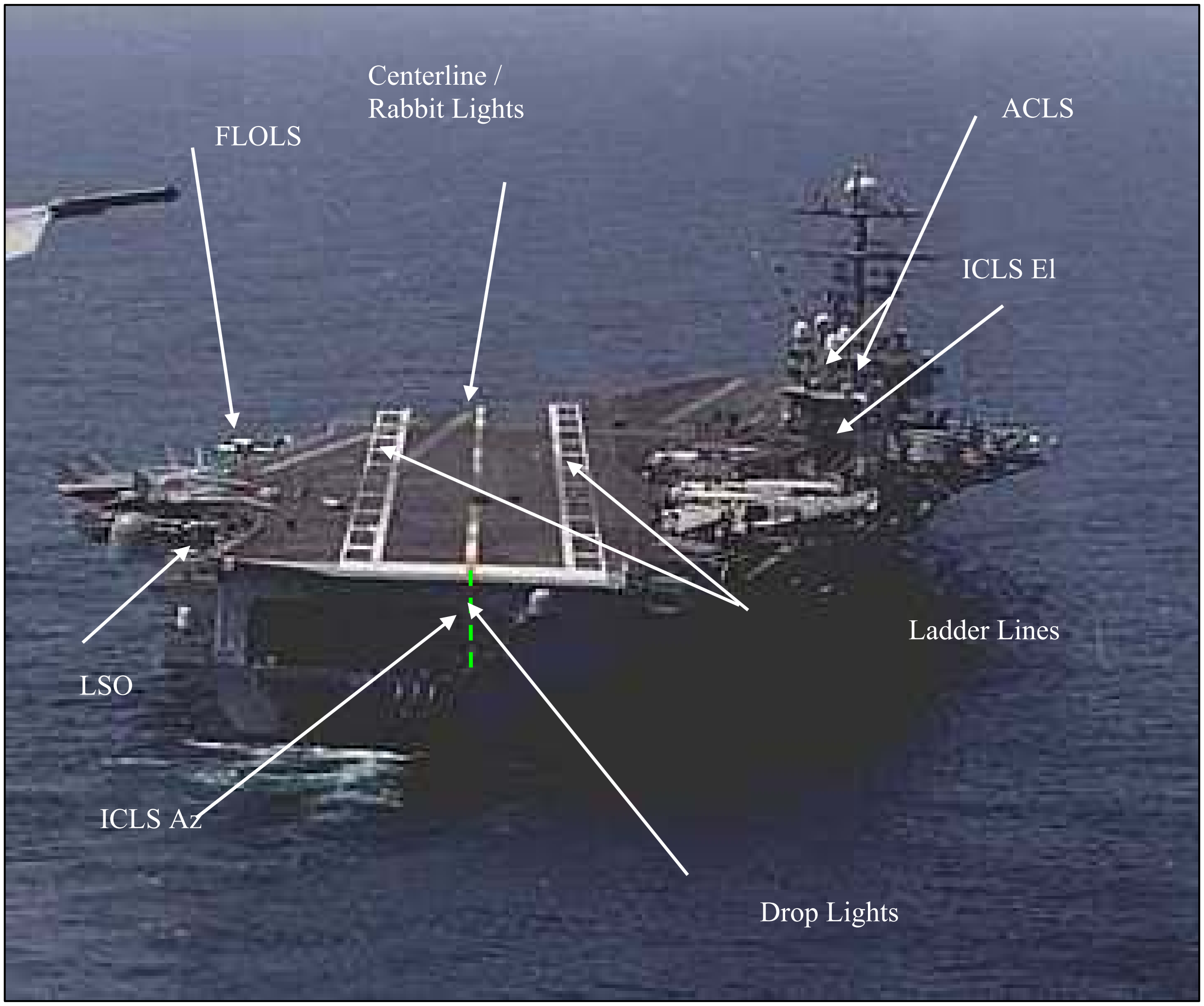

Figure 1: Aircraft Carrier Landing Aids

The LHA/LHD ships utilize the AN/SPN-35 Precision Approach Radar (PAR) and the ICLS. This branch is responsible for certification of PALS on all of the above ships. PALS ship certification requires periodic at-sea testing in order to ensure the system is performing correctly. PALS certification tests require two to four days of flight tests aboard the ship. This testing ensures that the ACLS/PAR and the ICLS are performing properly and that the ACLS, ICLS, and Optical Landing System (OLS) provide a unified presentation of aircraft position to the pilot. This branch is also responsible for the T&E of aircraft autopilot/auto-throttle modes to ensure compatibility with PALS. The unique autopilot/auto-throttle expertise developed in this branch is often called on to help in the design of these landing aids. Lastly, this group also evaluates U.S. Navy and Marine Corp aircraft compatibility, interoperability, and performance with international civilian precision approach and landing systems and provides Department of Defense liaison with the Federal Aviation Administration and International Civil Aviation Organization for air traffic control and landing system technology, systems development, and certification standards.

3.0 AVIATION PROGRAMS

3.1 Fixed-Wing Platforms

Currently, much of our ship suitability testing for air platforms is focused on modifications to current Fleet aircraft. In the fixed-wing area, much of our testing is concentrated on catapult launch and arrested landing structural tests (also called Shake, Rattle, and Roll Tests) of new or modified aircraft hardware, weapons, and avionics on all carrier-based platforms ranging from the F/A-18 Hornets/Super Hornets to the E-2C Hawkeye. Shake, Rattle, and Roll tests incorporate a series of shore-based catapult launches and arrested landings at the edges of the structural envelope to ensure structural compatibility of the test item in the shipboard environment. Recent examples of more complex testing include the shipboard lateral asymmetry envelope expansion test for the F/A-18E/F Super Hornet to give the Fleet additional flexibility in weapons loads and the shore-based and shipboard evaluation of the E-2C NP2000, which incorporates the new 8-bladed propeller (Figure 2). This same NP2000 propeller configuration will soon be tested on the C-2 Greyhound.

Figure 2: E-2C Hawkeye 2000 Conducting Tests aboard the USS JOHN F KENNEDY (CV67)

With respect to upcoming programs, we expect to commence shore-based testing of the EA-18G in 2007. Ship suitability tests of the EA-18G will be focused on arrested landing structural suitability due to the increased landing gross weight of this variant and FQ&P with the new external store configuration. We will be testing the new Electromagnetic Aircraft Launching System (EMALS) in 2007 and the Electromagnetic Aircraft Recovery System (EARS) in 2008. JSF ship suitability testing will commence in 2007 with the F-35B STOVL airplane. The F-35C CV airplane is expected to commence ship suitability testing in 2009. The E-2 Advanced Hawkeye should commence ship suitability tests in 2009. Ship suitability test areas for the Advanced Hawkeye will concentrate on the structural suitability due to the increased operating gross weight. The J-UCAS will commence a shore based catapult launch and arrested landing demonstration, which will be unlike any tests that we have conducted due to the unique challenges of testing unmanned aircraft discussed later in this paper.

3.2 Rotary-Wing Platforms

In the rotary-wing area, much of our current testing is concentrated on testing highly modified versions of current aircraft. The H-60R, H-60S, and UH-1Y/AH-1Z, are all modified versions of current Fleet aircraft undergoing ship suitability tests. Shipboard testing of the V-22 is ongoing as the team continues to expand shipboard launch and recovery bulletins and evaluate interaction with other aircraft (Figure 3). Upcoming tests include ship suitability tests of the new presidential helicopter (2008) and the new heavy-lift helicopter (2012). This branch will also be involved with interoperability testing of Army, Air Force, and Coast Guard helicopters on air-capable ships. Specific ship programs will be discussed later in this paper.

Figure 3: V-22 Conducting Interaction Tests Aboard the USS WASP (LHD 1)

3.3 ATC&LS Testing

ATC&LS testing is currently focused on certification of the PALS onboard LHD, LHA, and CV/CVN class ships. PALS capabilities are further described in Table 1. The ATC&LS Branch also certifies shore-based installations of the ACLS and ICLS and tests Instrument Landing Systems on all Navy/Marine Corps aircraft. Upcoming work is focusing on service life improvements of the current systems and development of the Joint Precision Approach Landing System (JPALS). JPALS will be used by all U.S. Services to provide shore-based and shipboard precision approach capability using relative GPS technology. The JPALS T&E program will be a large challenging program that will, in the end, enable a change to the concept of operation for the carrier air traffic control system and be the major enabling technology for UCAS shipboard launch and recovery operations. This branch is also heavily involved in new aircraft development programs such as the F-35B/C JSF airplanes and in the development of modifications to current airplanes such as the new Digital Flight Control System (DFCS) for the EA-6B.

Table 1: PALS Capabilities Description

System	Ship	Capability Description
AN/SPN-46 ACLS	CV/CVN	- **Mode I**: Hands-off approach to touchdown. - **Mode IA**: Hands-off approach to ¾ NMI, pilot takeover. - **Mode II**: SPN-46 radar provides azimuth and elevation guidance. - **Mode III**: Ground-controlled approach utilizing the SPN-46 radar for skin track. - Mode I, IA, and II capabilities require aircraft to have a radar beacon and an on-aircraft data link.
AN/SPN-41 ICLS	CV/CVN LHA, LHD	- SPN-41 radar provides azimuth and elevation guidance - Stand-alone instrument landing system or independent monitor for ACLS approaches. - Requires receiver in aircraft
AN/SPN-35 PAR	LHA, LHD	- Ground-controlled approach using radar skin track - No on-aircraft systems required.

4.0 SHIP PROGRAMS

4.1 Air Capable and Amphibious Assault Ships

The Navy is in the process of revolutionizing the Fleet. Leading that revolution will be the Littoral Combat Ship (LCS), which is specifically designed with a shallow draft and for operations with UAV's. This fast-paced program will see two ships in operation by 2008. As a pre-cursor to the LCS, the Navy is building a Littoral Surface Craft-Experimental (X-Craft), christened Sea Fighter (FSF 1) to evaluate the hydrodynamic performance, structural behavior, mission flexibility, and propulsion system of high-speed vessels and test a variety of technologies, which will allow the Navy to operate more effectively in littoral or near-shore waters. The DDX destroyer will be a revolutionary design that will be significantly different from current destroyers in both internal systems and external configuration.

Figure 4: General Dynamics and Lockheed Martin LCS

The LDP 17 multi-mission San Antonio class ships (Figure 5) will be the first ships designed to accommodate the tilt-rotor MV-22 Osprey aircraft, the advanced amphibious assault vehicle (AAAV), and the landing craft air cushion (LCAC). LPD 17 aircraft compatibility testing will commence this summer using conventional helicopters, the V-22, and the AV-8B.

Figure 5: USS San Antonio (LPD 17)

On a much larger scale is the Maritime Pre-Positioning Force Future (MPFF), which will carry out the Sea Basing mission of Sea Power 21. The exact configuration of this ship is still being finalized; however, one of the early design considerations was a very large ship with a flight deck that could handle C-130 sized aircraft. The Navy is also in the process of designing a ship to replace the LHA Amphibious Assault Ships. This design, designated the LHA(R), will be optimized to handle both the V-22 and F-35B STOVL JSF and is expected to enter the Fleet in the 2013 timeframe.

4.2 Aircraft Carriers

The evolution of the aircraft carrier will continue with the USS GEORGE BUSH (CVN 77), the tenth NIMITZ Class carrier, which will enter the Fleet in 2008. Like the USS RONALD REAGAN (CVN 76), which is now fully operational, this ship continues to optimize on the NIMITZ Class designs with the most significant changes in the topside design being the use of three vice four arresting wires and the movement of the island structure aft (Figure 6) to optimize flight deck space. The evolution becomes more of a revolution with the CVN 21. While this ship is still in the early design phase, the biggest change from an aviation standpoint will be the incorporation of the EMALS and EARS. EMALS and EARS will replace the steam catapult and hydraulic arresting gear systems that have served the Navy so well for the last 50 years. The most significant benefits of EMALS will be that the ship will no longer have to generate the huge amounts of fresh water to generate steam for each catapult launch and the ability to utilize a closed-loop control system, which will significantly reduce variation in launch endspeeds resulting in reduced aircraft loads. EARS will also use a closed loop system that will reduce arrested landing loads. Lastly, the topside deck design of CVN21 is also optimized to the makeup of the future Air Wings to optimize aircraft flow and parking spots, resulting in increased sortie rate over the NIMITZ class ships.

Figure 6: USS RONALD REAGAN (CVN 76)

5.0 UAV / UCAS PROGRAMS

5.1 Small and Medium Sized UAV's

Small UAV's are becoming more prevalent aboard ships. These air vehicles are being developed to both augment and/or replace manned aircraft. These UAV's use many unique forms of launch and recovery techniques, including pneumatic and bungee catapults, bungee style arresting gear, capture nets, and harpoon-type holddowns. Additionally, UAV's have a variety of methods of control systems for launch and recovery from fully automated to manually controlled systems. The RQ-8 Firescout Vertical Takeoff UAV (VTUAV) shown in Figure 7 is currently undergoing flight test in preparation for ship compatibility tests.

Figure 7: RQ-8 Firescout Vertical Takeoff UAV

5.2 Unmanned Combat Air System (UCAS)

The X-45 and X-47 J-UCAS aircraft shown in Figure 8 will pose a significant challenge to the operations aboard aircraft carriers. These F-18-sized aircraft will be required to intermingle with manned aircraft in the carrier environment in areas such as taxiing in the tight confines of the carrier deck, catapult launch, and arrested landings, and utilization of common support infrastructure. UCAS aircraft will also change the concept of operations for the carrier-controlled airspace as we learn to optimize the approach and departure corridors around the aircraft carriers. Testing on the X-45C and X-47B aircraft will commence in the 2006/2007 timeframe. A ship suitability demonstration using the shore-based catapult launch and arrested landing facilities at Patuxent River and Lakehurst will commence in the 2008 timeframe.

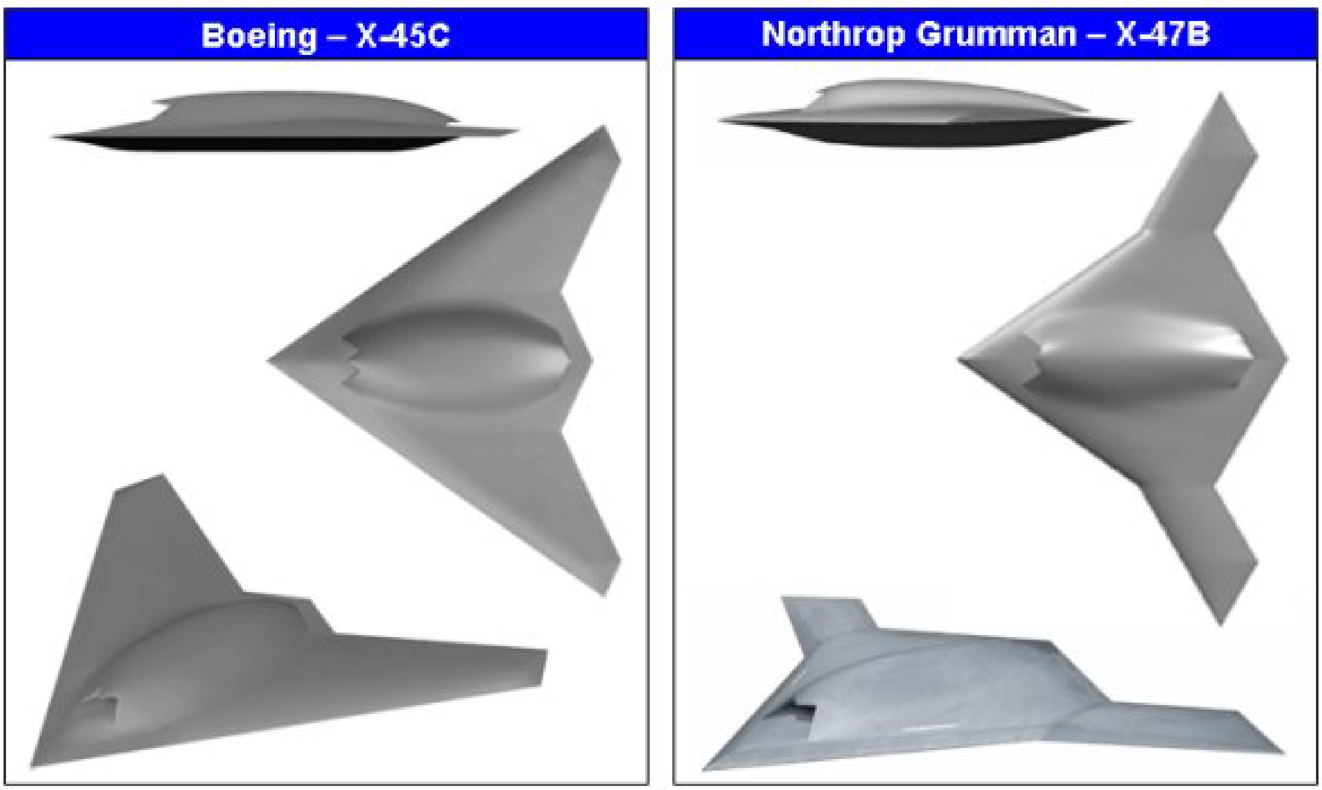

Figure 8: X-45C and X-47B J-UCAS

6.0 CHALLENGES

6.1 Demonstrators

So how do we brace ourselves for this testing and what are the significant challenges upon us? One method is to use demonstrators to evaluate technology and define concepts of operation. In preparation for LCS, the Navy has purchased two High Speed Surface Vessels (HSV's). We have already conducted DI testing with manned helicopters to evaluate the facilities and provide a launch and recovery envelope for Fleet aircraft. These commercial derivative vessels come in advance of the X-Craft, and help us ensure maximum utilization of the LCS. The JPALS program is currently making use of surrogate aircraft – typically small civilian aircraft – to conduct much of the initial testing of the shipboard relative GPS systems in development. These aircraft provide greater on-station time and are much more cost effective for this initial testing.

6.2 Modeling and Simulation

Aside from the conventional use of modelling and simulation (M&S) to evaluate aircraft handling qualities and performance in the shipboard operating environment, we also use M&S to evaluate the shipboard interfaces. Examples include the use of wind tunnel and CFD to calculate the airwake generated by the ship moving through the air mass. We are now plugging these airwake data into offline and/or manned simulations to evaluate effects on aircraft performance during launch and recovery operations. This enables us to evaluate the effects of the ships topside configuration on aircraft compatibility early in the design process when cost effective changes can still be made. This type of work has been recently done to support the CVN-21 design effort. We also use the airwake tools to evaluate more localized effects such as proposed wind anemometer locations and determine position errors. M&S is also used to give us insight into more subtle topside design items such as evaluating several proposed locations of visual landing aides (VLA's) for possible line-of-sight blockages during aircraft approach. This work was most recently conducted in support of the CVN77 topside design.

6.3 UAV/UCAS

The most challenging area in aircraft/ship compatibility is the integration of the UAV's and UCAS aircraft in the shipboard environment. Everything must be reconsidered, including shipboard facilities such as fueling and servicing and the Integration of the Mission Control Station into the aviation control areas such as Primary Flight Control, the Carrier Air Traffic Control Center (CATCC) and the Landing Signal Officer control station. Other significant factors in the T&E of UAV/UCAS aircraft include determining the test requirements from a flying qualities and structural suitability standpoint. The issues we must tackle include how to determine what is considered acceptable aircraft flying qualities. For example, a UAV/UCAS aircraft may be performing well from the standpoint of landing at the required touchdown point. However, if that aircraft is working excessively hard to maintain approach path, there may be safety concerns from the approach monitors (e.g. landing signal officers) who are responsible for the safe conduct of recovery operations. Therefore, the performance may be deemed inadequate. From a structural standpoint, the issue becomes even more clouded. Fixed wing manned carrier aircraft undertake a rigorous catapult launch and arrested landing structural suitability demonstration. Catapult launch tests include launches at the maximum structural limitations, usually longitudinal acceleration and launch bar load. Arrested landing tests require landings at conditions which include high-sink-rate landings (target sink rates in excess of 20 fps at several pitch attitudes), off-centerline arrestments at maximum hookload, landings with the aircraft in a rolled and yawed attitude, and free-flight landings where the arresting gear wire is picked up prior to main landing gear touchdown. In manned aircraft, these unusual approach profiles are flown by an experienced test pilot. It will be a challenge to program an automated aircraft to achieve these difficult test points.

6.4 Data Collection and Analysis

Data collection and analysis will also pose significant challenges. One such challenge involves the JPALS T&E program where we must collect and analyze (to very exact tolerances) multi-source asynchronous data obtained through several different methods. Another challenge will be determining suitability of UAV/UCAS aircraft without the qualitative evaluation of a test pilot, which is so critical for manned aircraft, even when evaluating auto-pilot systems. The JSF T&E program will also challenge us from a magnitude and complexity standpoint. The JSF STOVL and CV test aircraft will be able to generate large amounts of data. Our ability to evaluate all of this data in a timely manner will stretch our manpower resources. Another challenge is the logistics of setting up data collection and analysis hardware on the ship. While portable data station capability has significantly increased over the past ten years, giving us the ability to monitor and analyze thousands of parameters, we are normally limited by the amount of space aboard a ship to set-up these data stations. Automated data collection and analysis databases are being developed, largely through the efforts of our testers. They are researching many different areas including tools to speed up flight test analysis, predictive tools to reduce dynamic interface test requirements, and PC based tools to evaluate visual landing aids.

6.5 Test Procedures – Learning from the Past

As described above, we must develop new and innovative methods for testing future capability. However, we are also challenged in our need to learn from testing conducted in the past. We have seen a significant turnover in personnel since the last time we conducted sea trials with a STOVL aircraft. With upcoming AV-8B testing on LPD-17 and testing of the new JSF F-35B STOVL, we will research and understand the test techniques utilized during AV-8B testing last conducted in the 1980's. Additionally, we will be required to demonstrate ski-jump capability on the JSF F-35B. Much of our expertise in conducting ski jump testing has diminished over time. Going back even further in time, we were asked to evaluate the possibilities of landing C-130-sized aircraft on carrier-sized flight decks in support of design trade studies for the MPF(F) program. The C-130 was evaluated aboard the USS FORRESTAL (CV59) in 1963 (Figure 8). Information provided in the test reports and contact with the testers was used to help us examine ship suitability issues for the latest design considerations.

Figure 8: C-130 Landing aboard the USS FORRESTAL (CV 59), 1963

7.0 SUMMARY

In summary, we are entering a significantly challenging period of ship suitability T&E. The ship suitability test and evaluation testers must be able to utilize cutting edge tools to enable safe and efficient conduct of these tests while mixing in the lessons learned from testing that was conducted as far back as 40 years. From modelling and simulation to test planning aids to the latest capabilities in instrumentation and data analysis, we must challenge ourselves to conduct testing with safety as the number one priority while still giving the Fleet the best product possible. All the while, we are challenged to conduct this testing with less personnel than history tells us is necessary. This paper does not answer many questions, but poses the challenges that are ahead of the Ship Suitability Test and Evaluation group.